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AGRICULTURAL MEMORANDUM NO 548

An annotated bibliography on the effects of mulching on plant climate, with some comments on consequent yields.

Part IV - Effects on erosion and soil physics

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Parts I, II and III of this bibliography were issued as Agricultural Memoranda Nos 392, 423 and 523.

4.1 NO SPECIFIC CROP

The structure of a soil was improved under a permanent grass sward according to Goode (4), while Parr (5) shows that the bulk density of a soil was lower a year after vertical mulching with straw, than after subsoiling. Duley (1) meanwhile presents data to show that a mulch of plant residues greatly increased the rate of intake of water into the soil and at the same time reduced run-off and erosion. The effect of both organic and non-organic mulching materials was studied by Tukey (10), who maintained the mulches to a depth of 15 cm over 5 years. He reports that differences in soil aeration associated with the texture of the mulch were much greater than any differences associated with a differential nutrient supply or rate of decomposition of the materials used.

Experiments on loam and silt-loam soils of 3-4½% slope using a simulated rainfall of 60 mm/hour intensity are reported by Mannering (6). Different applications of maize stalks reduced soil losses in the following decreasing order; stalks shredded after picking, shredded stalks disced once, stalks left after picking. In a later paper (9) he used a 5% slope on a highly permeable silt-loam and subjected it to simulated rainfall of 160 mm at 60 mm/hr intensity. He found that a straw mulch of 2.5-10 tonnes/ha maintained infiltration rates at high levels and prevented soil loss by run-off, while mulching at 0.5 to 1.2 tonnes/ha resulted in a soil loss of 2.5 to 7.5 tonnes/ha. The reduction of soil loss from 12 tonnes in unmulched plots to the amounts quoted above was mainly due to the lower soil content of the run-off.

Chepil (8) compared the effectiveness of different materials in controlling erosion. Fine, medium and coarse gravel at rates of 50, 125 and 250 tonnes/ha respectively, adequately controlled wind erosion on a smooth bare sandy loam, as did a resin emulsion sprayed at 0.7 litre/sq.m and an asphalt emulsion sprayed at twice that rate. Latex emulsion sprayed at rates up to 0.25 litre/sq.m was not sufficient to control wind or water erosion on level or sloping ground. On a 3:1 construction slope, asphalt emulsion at the rate of at least 1.4 litre/sq.m was needed to control rill erosion; a hay mulch of 4.5 tonnes/ha uniformly spread and anchored with an asphalt spray was equally effective. Siddoway (11) however, shows that wind erosion varied exponentially with the amount of residue on the soil surface in a wind tunnel experiment. In general, fine textured residues on a weight basis, were much more effective than coarse textured residues. Relatively small amounts of even the coarsest residues resulted in sizeable reductions in erodibility compared with bare soil.

Grain straw applied at 5 tonnes/ha is shown by Barnett (13) to provide adequate protection to newly prepared and seeded $2\frac{1}{2}$:1 backslopes when subjected to 33 mm of rain in 30 minutes. The loss of soil was reduced from 240 tonnes from bare unprtected slopes to about 25 tonnes with the mulch. Jordan (14) meanwhile, found that the crumb structures of soils treated with very thin bitumen mulches (150 μ thick) were able to withstand considerably more weathering by rainfall or irrigation than unmulched soil before breakdown of the soil surface structure occurred.

A rainfall simulator and soil-filled run-off boxes (micro-watersheds) were used by Hillel (15) to examine the effects of light fuel oil and emulsions of latex, asphalt and wax, on infiltration, run-off and erosion. At various rainfall durations and application rates three interacting effects were observed: I. a hydrophobic effect which disappeared after the surface became saturated; II. a structure stabilising effect which decreased the slaking and self-crusting tendency of the loose soil (as well as its erodibility) and increased the infiltration rate; III. a surface-sealing effect which at higher application rates effectively sealed the surface and decreased the infiltration rate below that of the untreated soil. Of the materials tested, fuel oil appeared to be the most efficient for run-off inducement.

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4.2 TEMPERATE TREE FRUITS

Clean cultivation practices in hillside orchards in Japan have led to serious soil erosion. Shibukawa (1) and (6) recommends that sod culture is used to improve conditions despite its competition for nutrients and moisture. On seriously eroded soils, structure must be improved by the addition of organic matter before a sod can be established. In USA, Toenjes (2) also noted that the physical condition of the soil in clean cultivated plots became progressively worse over the years compared with plots with sod cover. The worsened condition greatly retarded absorption and penetration of rainwater and the resulting run-off caused some soil erosion.

In France on a poor calcareous soil in a dry-farming area, various mixtures of barley, oats and clovers were sown as green manure in orchards (3). They were cut once or twice a year and left as a mulch and complete control of erosion was established as one of the few definite conclusions possible, after 2 years. Similar methods were used in Germany by Löhrke (4) who checked erosion and improved soil structure by leaving the mown crop as a mulch for 10-12 weeks in spring before discing in.

Experiments in a Bavarian apple orchard are described by Rid (7). The beneficial effects of deep cultivation (down to 40 cm) were still evident after 10 years, the topsoil having a somewhat greater pore space and the subsoil a lower resistance to shearing. Regular annual mulching and heavy mineral fertilization increased pore space and reduced soil density down to 30 cm in depth, thus improving permeability and aeration. Such benefits were particularly beneficial to soil structure under conditions of impeded drainage and in districts with high rainfall.

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4.3 TEMPERATE HORTICULTURE AND SOFT FRUIT, VEGETABLES AND FLOWERS

During a very wet season in Hungary, Fekete (1) reports that soil structure was less affected by raindrop impact in plots mulched with organic materials than in non-mulched control plots, while Watson (2) claims better aggregation of soil particles using a mulch of ground corncobs at various thicknesses around rose bushes. On shallow, sandy soils of very poor structure in France, straw mulching at 10 tonnes/ha led to superficial gley formation, but in the 2 following years Hénin (6) reports that straw applied at half rate and incorporated when partly decomposed, progressively improved soil structure. Ells (11) evaluated an asphalt emulsion, sand and perlite in the seed furrow for prevention of soil crusting. Perlite, trailed in a 6 mm groove over the seed row, was the most practical method in the USA.

Heady (3) conducted an experiment for 4 years in an area in California with 890 mm annual rainfall, using different amounts of mulch varying from 0 to 5.5 tonnes/ha. He found that soil erosion during intensive rainfall was observed only on the plots where all the mulch was removed each year. In Ceylon, tillage for weed control causes soil erosion according to Kirinde (4) and while cover crops and mulches protected the soil against erosion, they did not control weeds.

Onchev (7) shows that mulching decreased erosion and run-off on 10-11° slopes in a vineyard in Bulgaria. Straw was more effective than maize stalks and mulching the entire surface was more effective than mulching in bands. To prevent crust formation and erosion on sloping sites in Ireland, mulching is recommended by Robinson (9) who preferred farmyard manure to straw. In a later paper (12) he found that although mulching was needed on erodible slopes it was otherwise unsuitable as it increased frost injury.

Sakamoto (10) reports that soil erosion and run-off in vineyards in Japan were greatest under clean cultivation and least under straw mulching. Under grass and clover sod mulches, erosion and run-off were high initially but were much reduced after the cover crop had become established. Nine years' observations on a German vineyard with a slope of 58% were made by Bosse (13). Plots were supplied at the rate of 200 or 400 tonnes of composted refuse per hectare in 1959, and were given another 200 tonnes/ha in 1965; the soil was either cultivated or mulched. The mulching reduced soil erosion to 58.5% (for 400 tonnes) and 33.3% (for 600 tonnes) of the amount of erosion occurring in the controls. Because of the steep slope, the total run-off (water plus soil) was less affected, being reduced to 77.1% (for 400 tonnes) and 55.1% (for 600 tonnes) of the controls. Non-cultivation further prevented soil erosion.

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4.4 FORESTRY

First year survival of seedlings is shown by Ursic (1) to be significantly increased by mulching. Small plots on barren, eroded sites with exposed mineral soils were planted in 1956 (when there was a dry summer) and in 1957, and a hay and straw or pine litter mulch was applied to all plots. Spot mulching of trees to a radius of 23 cm was as effective as broadcast mulching.

Zak (2) describes treatments on active sand-dunes, for the direct planting of shrubs and trees. These included mulching with fuel oil or asphalt at 0.16 or 0.33 litres/sq.m (according to exposure) compared with no mulching, with or without protection by 1 m sand terraces established between two 2 m strips of tall fescue grass.

After 2½ years, only the plots treated at the higher rate of fuel oil were promising. The mulch was in good condition and there was no erosion or root exposure and survival was around 50%. The other plots were poor, the terraces and the plots behind them being eroded. The tall fescue grass arrested moving sand but the strips were too narrow to protect the width of the plots behind them from severe scouring.

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4.5 GRASSES AND CEREALS

Duley (1) discusses the effect of stubble-mulch farming on controlling wind erosion, and conserving soil moisture with different amounts of residue to be left on the surface, while Melsted (2) reviews work on living mulches and intercrops, trash mulches and sod seedbeds on soil tilth and erosion control. Burnham (4) states, that in areas where precipitation averages 380-460 mm, a stubble mulch is essential to reduce wind damage and drying of surface soil, while Zingg (6) shows that stubble mulching reduced soil losses caused by heavy rainfall to 20% of those occurring with mouldboard ploughing. Average run-off was halved and wind erosion was also reduced. Power (8) also claims good erosion control with stubble mulching.

The following table is taken from preliminary results reported by Fenster (10). They are from run-off plots on a 4% slope carrying a wheat/fallow rotation in which the fallow is either stubble mulched or left bare.

	Fallow plots		Wheat plots	
	Stubble mulch	Bare	Stubble mulch	Bare
Run-off (mm)	2	35	32	75
Soil loss (tonnes/ha)	0.99	7.60	1.67	14.16

Greb (12) meanwhile used sorghum stubble to reduce wind erosion during summer in areas where a wheat/sorghum/summer fallow rotation is practised. Undisturbed stubble lost about 33% of its weight during the winter. Subsurface tillage during the fallow period, as distinct from disc harrowing, preserved up to 45% of the original stubble.

Mulch tillage (manuring followed by cultivation on meadow sod) considerably reduced run-off and erosion according to Beale (3), and a similar method was used by Borst (5) with manure at the rate of 25 tonnes/ha or wheat straw at 5 tonnes/ha to reduce the average run-off on 10 and 12% slopes by 58 mm and to reduce erosion by 29.4 tonnes/ha. However, in a 5 year trial on sloping ground in Indiana, Mannering (29) found that minimum tillage for maize compared with conventional tillage, increased infiltration and reduced soil erosion. A surface mulch of 7.5 tonnes/ha of dry hay applied after the first cultivation eliminated soil and water loss during the rest of the crop season.

Mulching on salt affected soils in erosion trials is claimed by Logan (7) to permit establishment of lucerne and other grasses where none occurred on adjoining non-mulched plots. A mulch of lucerne hay (10-15 cm) is shown to give better results than sheepyard manure (2.5 cm) or sawdust (6-12 mm). Meanwhile, a film of an oil-

extended synthetic rubber compound applied to the surface of mobile sand was used by Haas (17) to provide sufficient stabilization for germination and growth of grass and for the continued deposition of sand. The film remained effective under exposure to sunlight for 6 months and resisted erosion from occasional covering by sea water. Harpaz (21) however reports on coastal sand dune surfaces in Israel which were sprayed with a synthetic rubber (1:5:20 emulsion of rubber in oil in water) pre-emergence spray to form a temporary mulch to aid plant establishment. The crust was sufficiently durable for temporary sand dune stabilization, and had no detrimental effect on emergence or growth rate of the three grass species tested, but Zak (30) states that mulches were of little value in establishing grass from seed in trials to control drifting sand dunes on Cape Cod.

In wind tunnel and laboratory trials, Simmons (24) reports that a 9:1 oil/rubber blend applied at 30% concentration in 0.16 litres/sq.m reduced evaporation and soil disturbance by wind, but allowed penetration by rainfall and by emerging grasses and clovers. In field trials, satisfactory establishment to the stage when roots of sown grasses bound the sand was obtained on coastal sand dunes in England and desert sands in the Negev.

In Australia, where rainfall is low and the climate is warm and dry a good grass cover was established on the steep infertile slopes of a reservoir by mulching with rain damaged meadow hay which helped to retain moisture (9). In an attempt to stabilize the soil rapidly and cheaply, Costin (14), also in Australia, compared mulches of natural straw with cereal straw. By the end of the first season the strips with natural mulch were about 75% covered by living vegetation, while those with cereal mulch had less than 25% cover. In the following year the difference was even more marked. Survival rates of summer grasses planted in winter in the USA, however, were unaffected by mulches of oat straw or a green coloured latex solution, but soil erosion was reduced by the mulching according to Thompson (16). In another USA trial, Zak (25) studied the effects of mulches of resin, latex, asphalt, sodium silicate, jute meshing, gelatin and hay on the germination of sown grass seeds. The effects were variable but none was superior to the untreated control.

Soil and water losses during a period of 9 years on silt loams of 8-16% slope were less from continuous maize mulched with stover (hay made from clover) and farmyard manure than from unmulched maize and oats in a ley rotation, equalling the losses from the hay crop in the rotation, according to Taylor (19), while Colbjørnsen (20) reports that spraying with bitumen emulsion was very satisfactory, under fair weather conditions, for the establishment of grass on slopes of 1.8:1. Richardson (23), however, claims that straw spread at 5 tonnes/ha was the best mulch for plant establishment on most steep road banks.

Another method (26) for establishing grass covers consists of a slurry of grass seeds or small sprigs of vegetative planting material, and a wood-cellulose fibre together with fertilizers (and pesticides where necessary). The slurry can be sprayed on to roadside verges, or inaccessible slopes at rates up to 1.2 ha in 15 mins. The effect is to form a fibrous mulch over the sprayed surface which controls erosion and serves as a good germination medium for the embedded seeds.

Straw, gravel or dioctadecyl dimethyl ammonium chloride (DDAC) treated soils were applied as mulches to 0.004 ha plots on a 4% slope by Adams (27). Run-off and erosion were greater from DDAC-treated soil than from bare soil, while a surface cover of straw or gravel significantly reduced run-off and eliminated erosion. During high rainfall, straw and gravel mulches increased infiltration and movement of excess water. However, Moldenhauer (18) recommends that to control erosion on exposed subsoils, mulches of wheat or oat straw at 5 tonnes/ha, asphalt spray at 1.1 litre/sq.m or 2 mm thick polyethylene film should be used.

The effectiveness of 8 mulching procedures for vegetation establishment and erosion control on a newly constructed roadside slope was investigated by Beard (28). Straw alone, straw plus asphalt and "Mulch-net" over straw mulches at seeding time were significantly superior to various manufactured mulches which, although providing initial soil erosion control, lacked the property of adequate soil moisture retention for the establishment of grasses. Turf gave equal erosion control.

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4.6 TROPICAL AND SUB-TROPICAL CROPS

Smith (2) reports on experiments in Puerto Rico over 20 years and shows calculations of the soil loss per inch of run-off per 1% slope for several crops and covers. In terms of resistance to erosion, the effectiveness varied from nil for desurfaced and 15% for normal fallow soil, to 98% for sugar cane with complete mulch and for tropical kudzu. Puerto Rican soils appeared to be 2-3 times as resistant to erosion

as soils in the temperate zone. In Brazil, meanwhile, Medcalf (3) claims that erosion control and soil conservation are among the major indirect benefits of heavy mulch applications in young coffee plantations.

The findings from 20 years of erosion control experiments in areas of poor vegetation on the Bombay Deccan are summarized by Kibe (5) who made detailed studies with leguminous crops. Results are tabulated for run-off and soil losses under different crops and under natural vegetation. Wang (6), however, compared plantings of pineapples in five different ways on a clay loam soil with a 1 in 5 slope in Taiwan. Bench terraces with 180 plants per plot mulched with rice straw (1), compared with 132 unmulched vertical rows per plot (2) resulted in run-off losses of 2.73% in (1) and 21.8% in (2) and soil erosion losses in 3 years from 0.124 tonnes/ha in (1) to 185.48 tonnes/ha in (2). Run-off and soil loss were greatest when the plants were young.

Under conditions in Barbados affected by erosion and by oil and salt in the soil, Cumberbatch (8) claims significant yield increases by mulching with bagasse and filter mud, and with sour grass. Strauss (9) however, found in California, that working sawdust into the ground 5 cm deep and spreading a second layer on the surface was better for erosion prevention than simply spreading it on the surface.

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Any comments or suggestions on this paper should be sent to the author.

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